



WBS 2.2

Liquid Scintillator

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Liquid Scintillator for NOvA

- NOvA's fiducial mass is dominated by its active detector medium – liquid scintillator
- NOvA is very large so it needs a very large mass of liquid scintillator

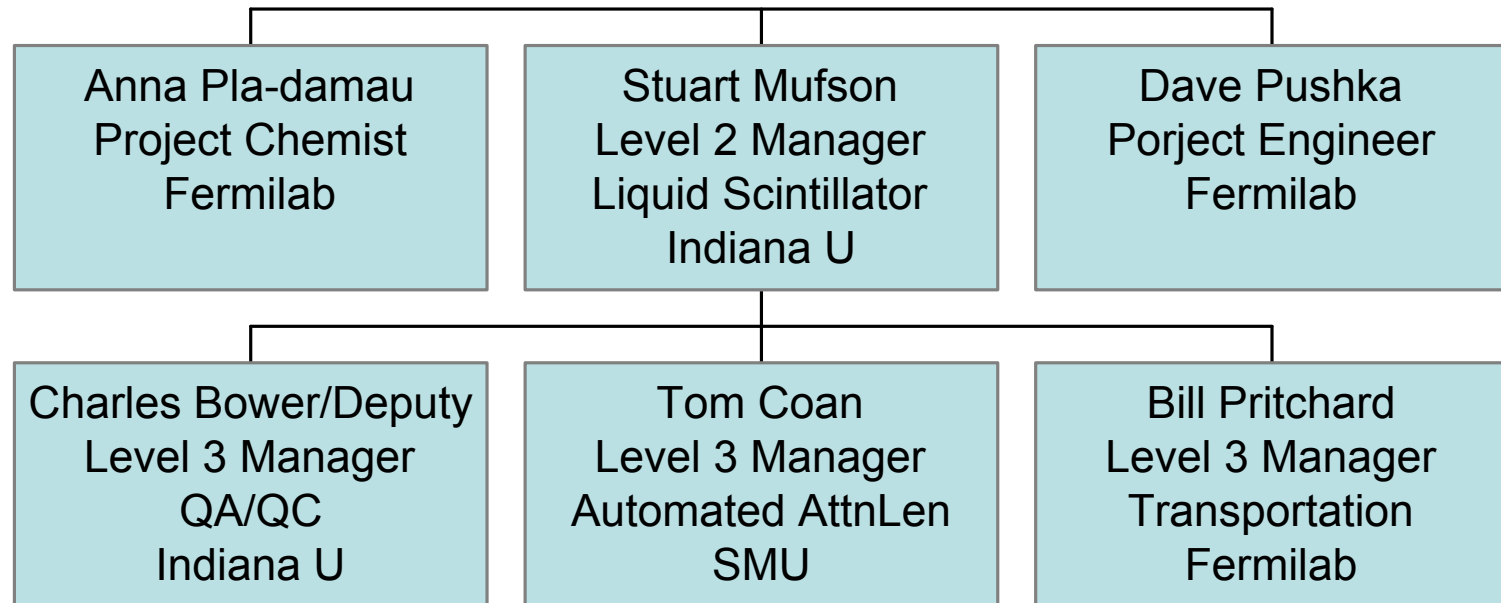
The NOvA detector requires 12.6 kilotons of liquid scintillator

- Requirements: the NOvA liquid scintillator must
 - be affordable
 - meet light yield and attenuation length requirements set by NOvA science
 - have a production and delivery schedule that matches the NOvA far detector construction
 - be delivered to the NOvA far detector with assurances that its quality keeps construction on schedule
 - minimize environmental hazards



Liquid Scintillator Organization Chart

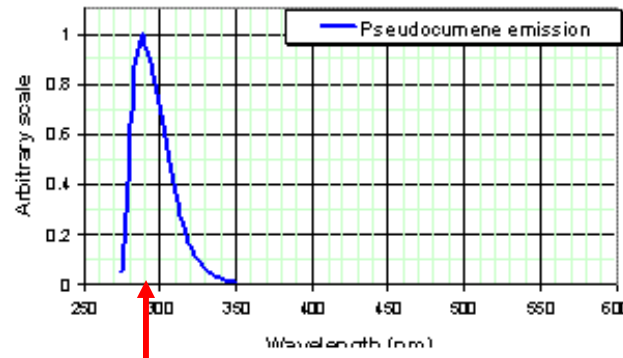
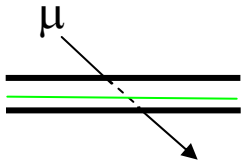
WBS 2.2



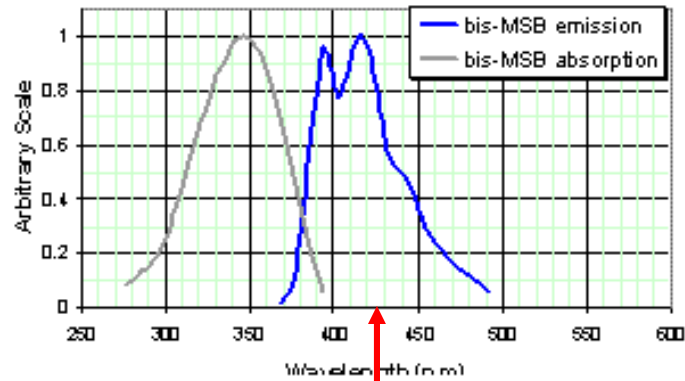
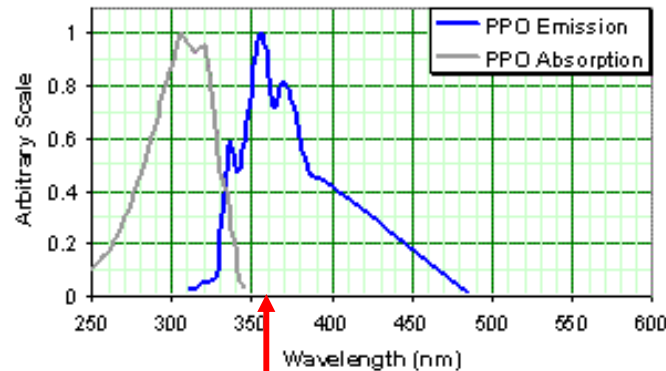


Scintillator Light Production

Pseudocumene [1,2,4-trimethylbenzene] is the primary scintillant that is excited by traversing ionizing particles; de-excitation produces UV photons

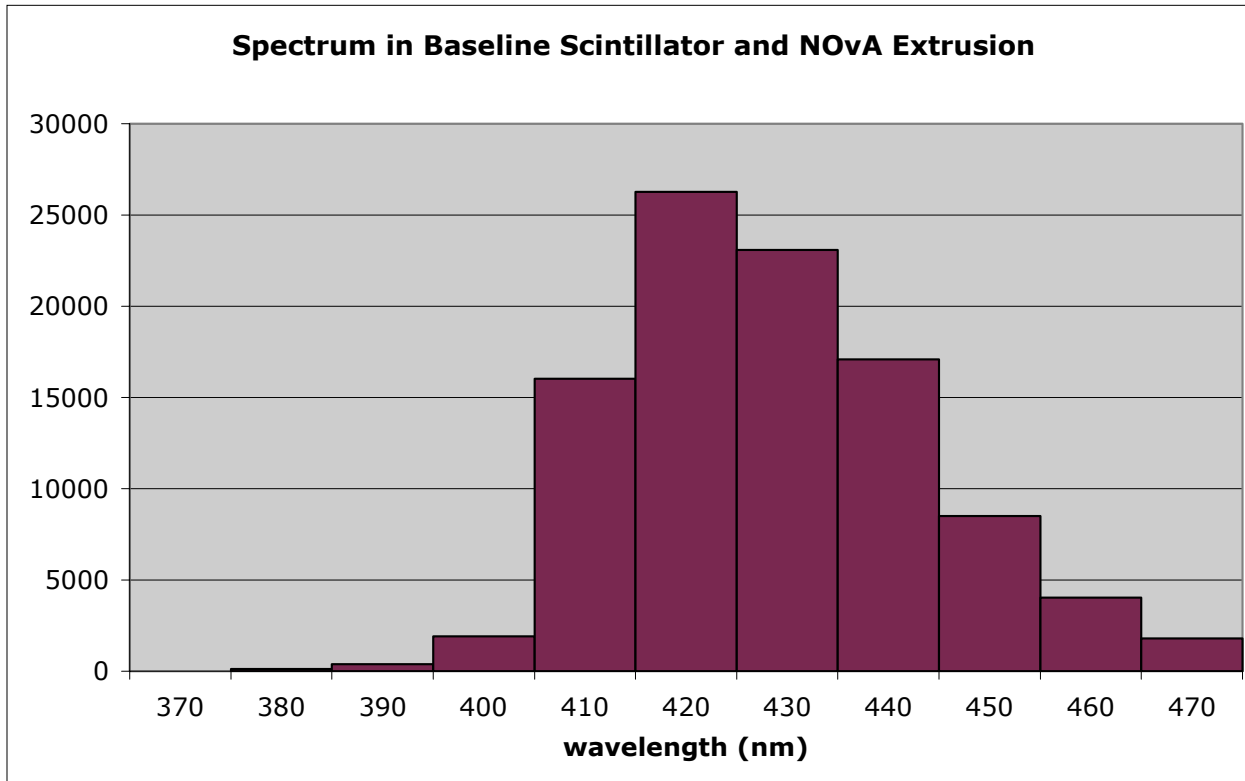


PPO [2,5-diphenyloxazole] and bisMSB [1,4di(methylstyryl)benzene] shift the UV photons to the visible range





Scintillator Light Production



Monte Carlo calculations of the spectrum of photons absorbed by the fiber for the baseline NOvA liquid scintillator in a prototype NOvA PVC cell in which the plastic is loaded with anatase TiO_2 and the light is collected by a 0.7mm WLS fiber



Liquid Scintillator for NOvA

Technical design requirements for NOvA liquid scintillator

	Technical Design Requirements
Light Output	Light Yield (NLS)/Light Yield (BC-517P) ≥ 0.75
Attenuation Length	AttnLen(NLS) $\geq 2.2\text{m @ } 420 \text{ nm}$
Conductivity	$\geq 100 \text{ picosiemens/meter}$

- Scintillator with: (1) light output equivalent to 75% Saint-Goban (Bicron) BC-517P and (2) attenuation length of 2.2 m meets the technical performance specification of 20 p.e. per mip for a particle at the far end of a NOvA cell.
- Technical requirement for conductivity taken from the recommendations by the National Fire Protection Association (NFPA) -- safe practices dictate that scintillator be made “semi-conducting”, or “possessing a conductivity $> 100 \text{ ps/meter}$ ”.



Liquid Scintillator for NOvA

Baseline Liquid Scintillator

component	purpose	mass fraction	volume (gal)	tot mass (kg)
<i>mineral oil</i>	solvent	94.4%	3,710,764	11,939,755
<i>pseudocumene</i>	scintillant	5.5%	209,246	693,863
<i>PPO</i>	waveshifter #1	0.1%		15,269
<i>bis-MSB</i>	waveshifter #2	0.002%		214
<i>Stadis-425</i>	antistatic agent	0.0003%		38
<i>tocopherol (Vit.E)</i>	antioxidant	0.0010%		126
Total		100.0%	3,920,010	12,649,158

**“Baseline
Fluors”**

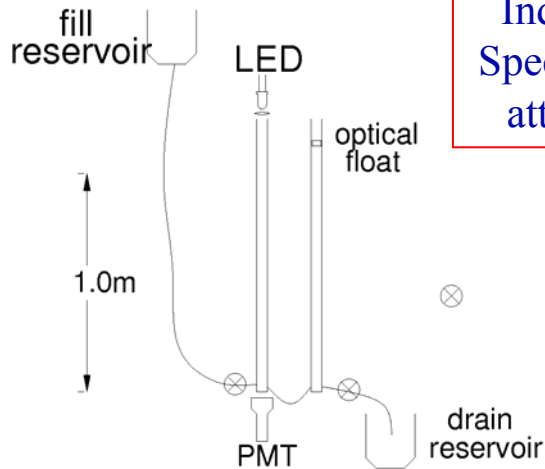
Detector: volume mass
@70F

The advantages of this mixture include:

- stability
- low cost
- low toxicity
- high flashpoint
- low potential as an environmental hazard
- safe for WLS fiber and PVC over lifetimes exceeding this experiment

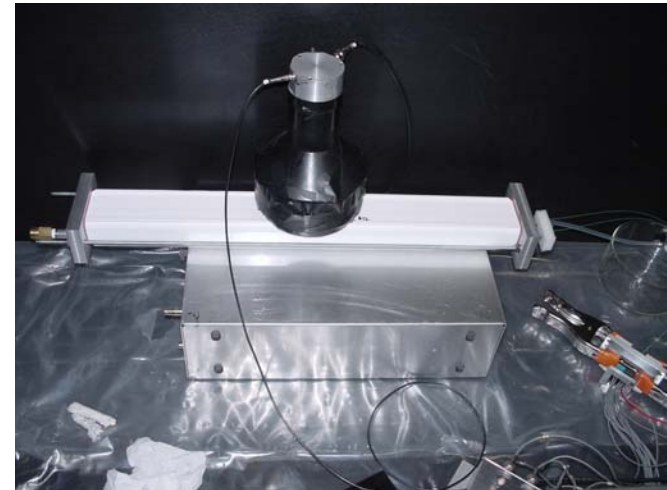


Measurement and QC Apparatus

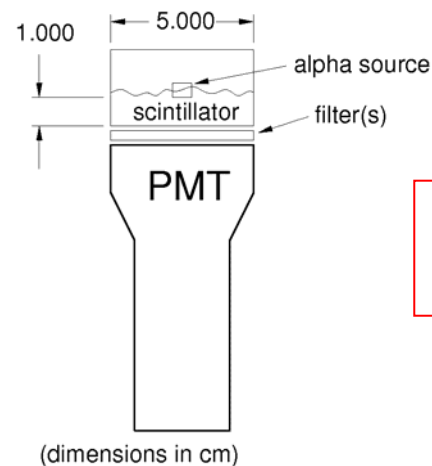


Indiana University
Spectrophotometer --
attenuation length

NOvA Cell -- light yield



Lovibond Tintometer -- QC transmission



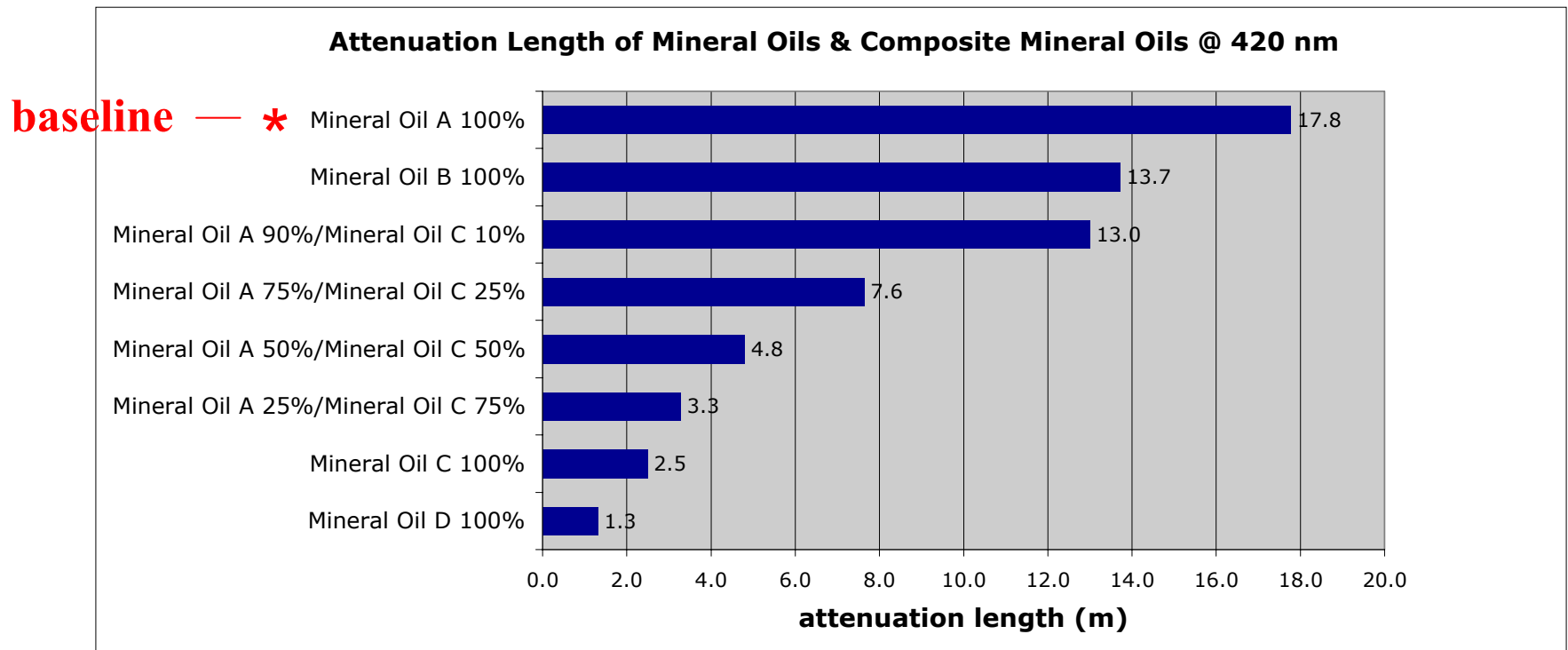
α -test --
composition



Technical Design Requirements: Mineral Oil

Liquid scintillator is mainly mineral oil.

- Four different technical grade mineral oils tested, labeled **A**, **B**, **C**, **D**.
- Attenuation length was tested in the IU Spectrometer

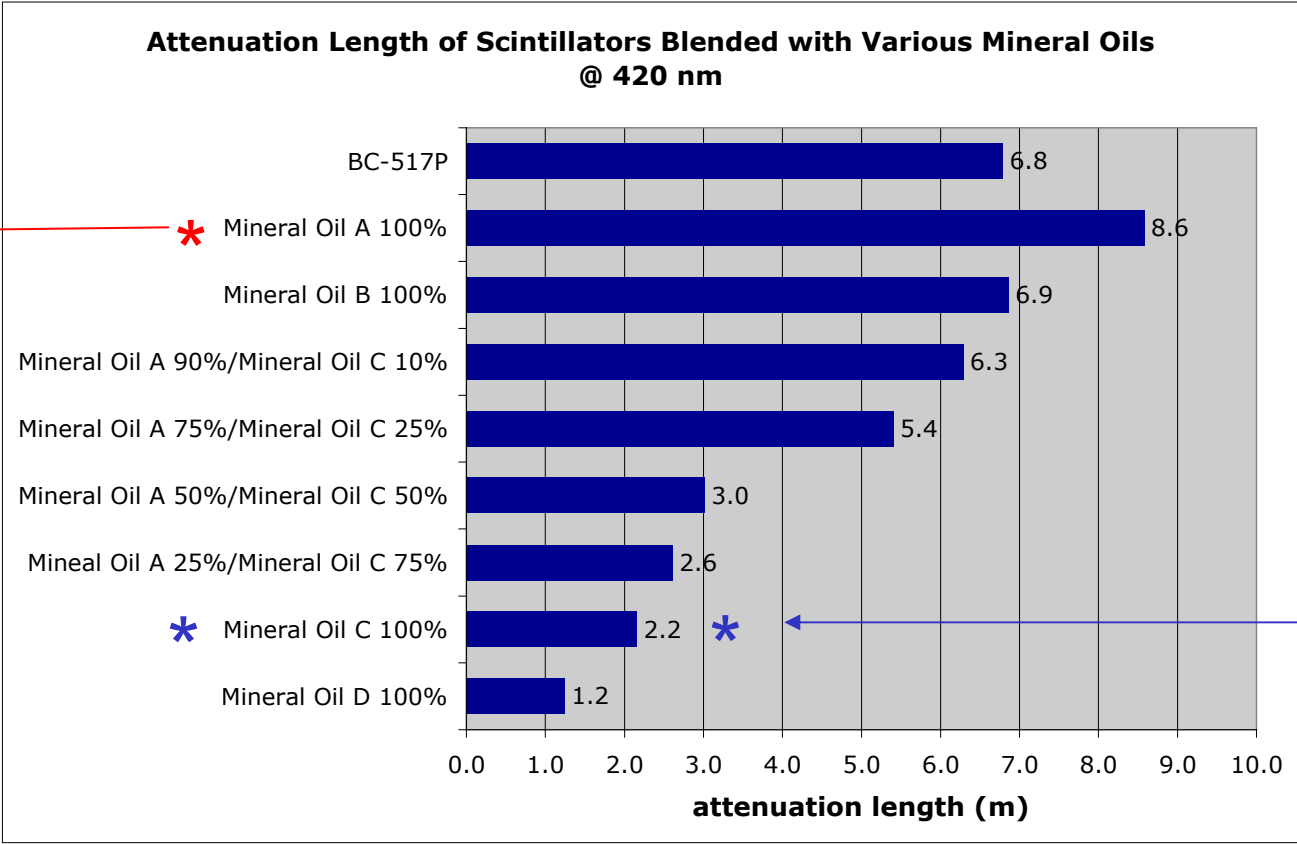


Attenuation length of Mineral Oils studied during R&D



Technical Design Requirements: Mineral Oil Attenuation Length

baseline



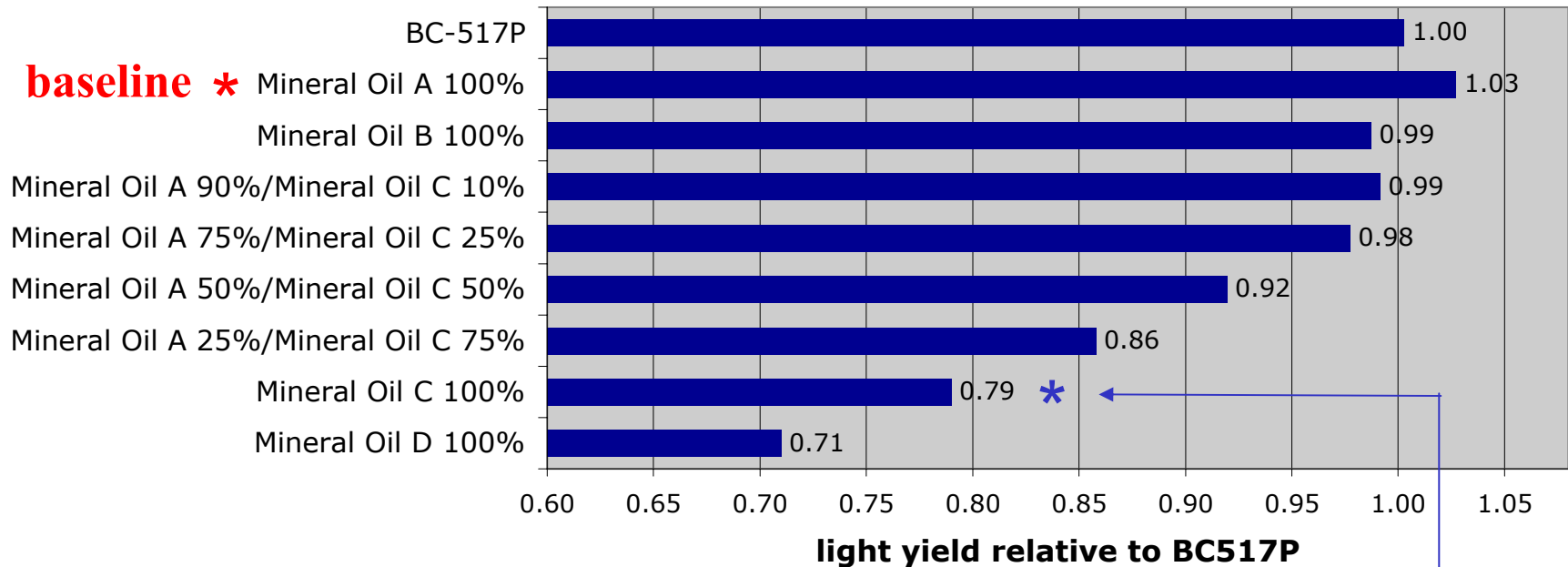
meets
design
specs

	Technical Design Requirements
Light Output	Light Yield (NLS)/Light Yield (BC-517P) ≥ 0.75
Attenuation Length	AttnLen(NLS) ≥ 2.2m @ 420 nm
Conductivity	≥ 100 picosiemens/meter



Technical Design Requirements: Light Yield

Light Yield of Scintillators Blended with Various Mineral Oils



	Technical Design Requirements
Light Output	Light Yield (NLS)/Light Yield (BC-517P) ≥ 0.75
Attenuation Length	AttnLen(NLS) $\geq 2.2\text{m}$ @ 420 nm
Conductivity	≥ 100 picosiemens/meter

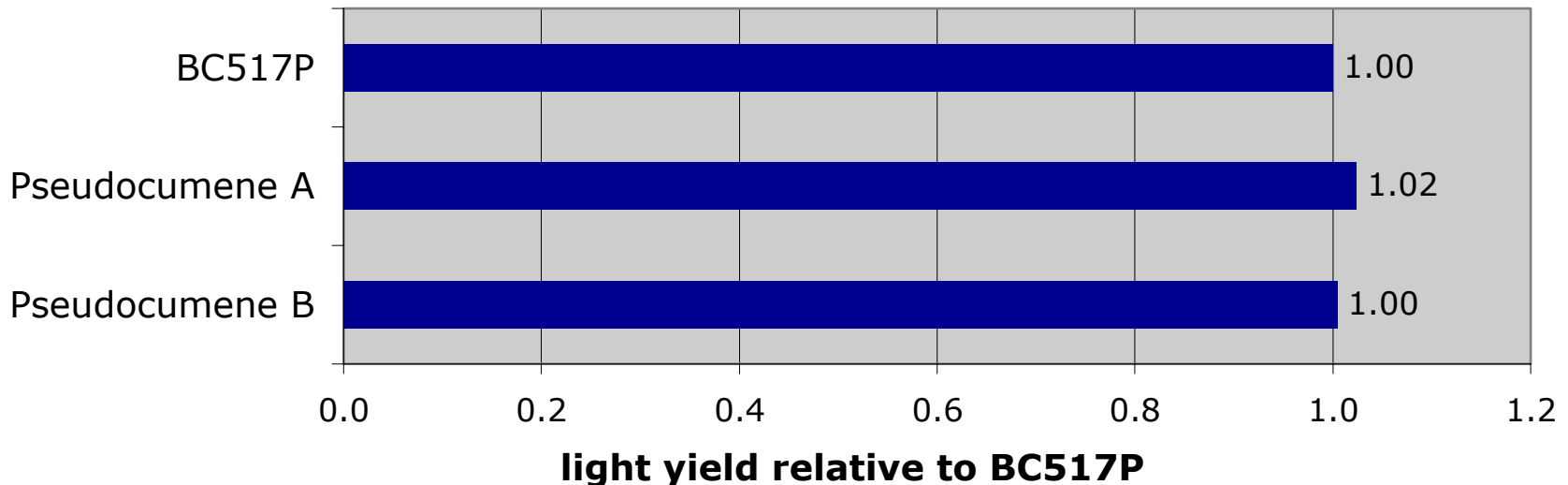


Technical Design Requirements: Pseudocumene

	Technical Design Requirement
Purity	□ 98%
specific gravity @ 60/60F	$0.875 < \text{specific gravity} < 0.882$
Clarity	$< +25$ Color Units measured on Pt-Co scale
Total Sulfur content	< 2.0 ppM

Pseudocumene obtained from two suppliers. They are equivalent

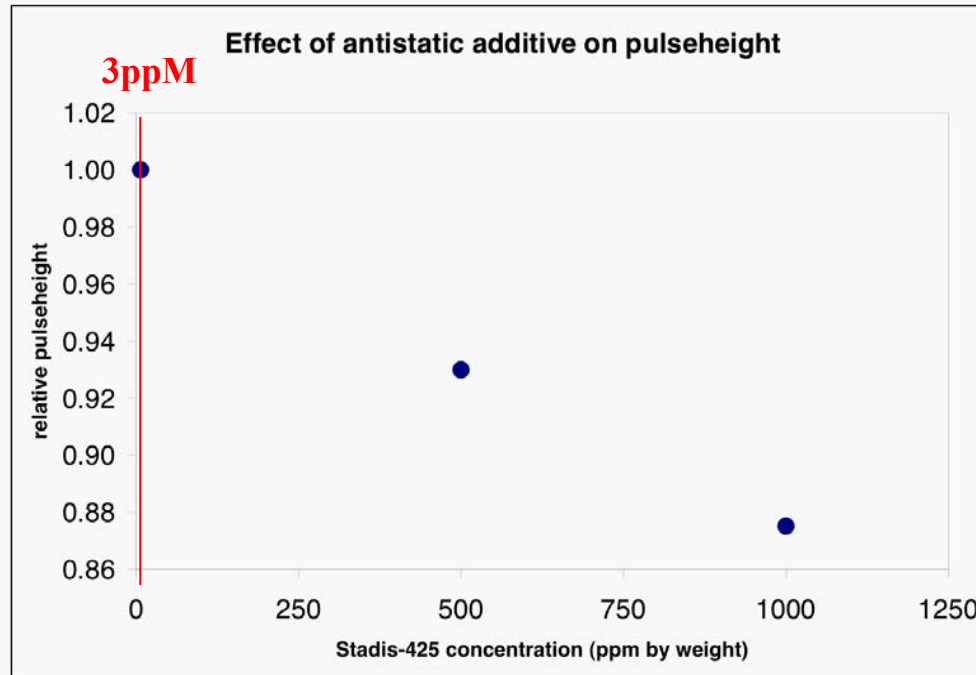
Light Yield of Scintillators Blended with Pseudocumene from Different Suppliers





Technical Design Requirements: Stadis 425

relative pulse height



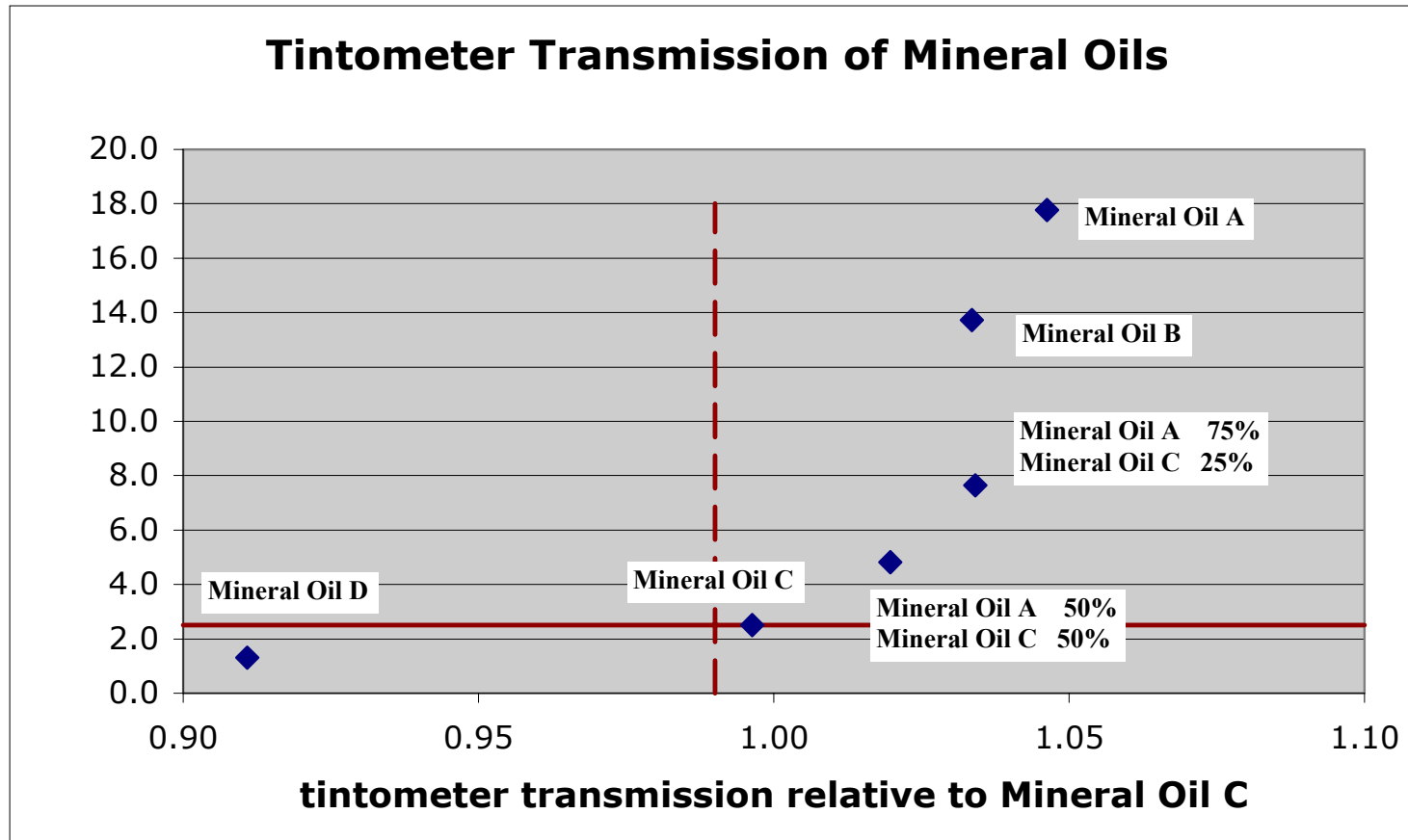
Stadis-425 concentration (ppM by weight)

- Adding 3 ppM of the anti-static agent Stadis-425 guarantees the scintillator will be semi-conducting
- At 3ppM, there is no adverse effect on the light yield.



QA/QC -- Mineral Oil Attenuation Length

Quick, simple testing with Lovibond Tintometer: Mineral Oil

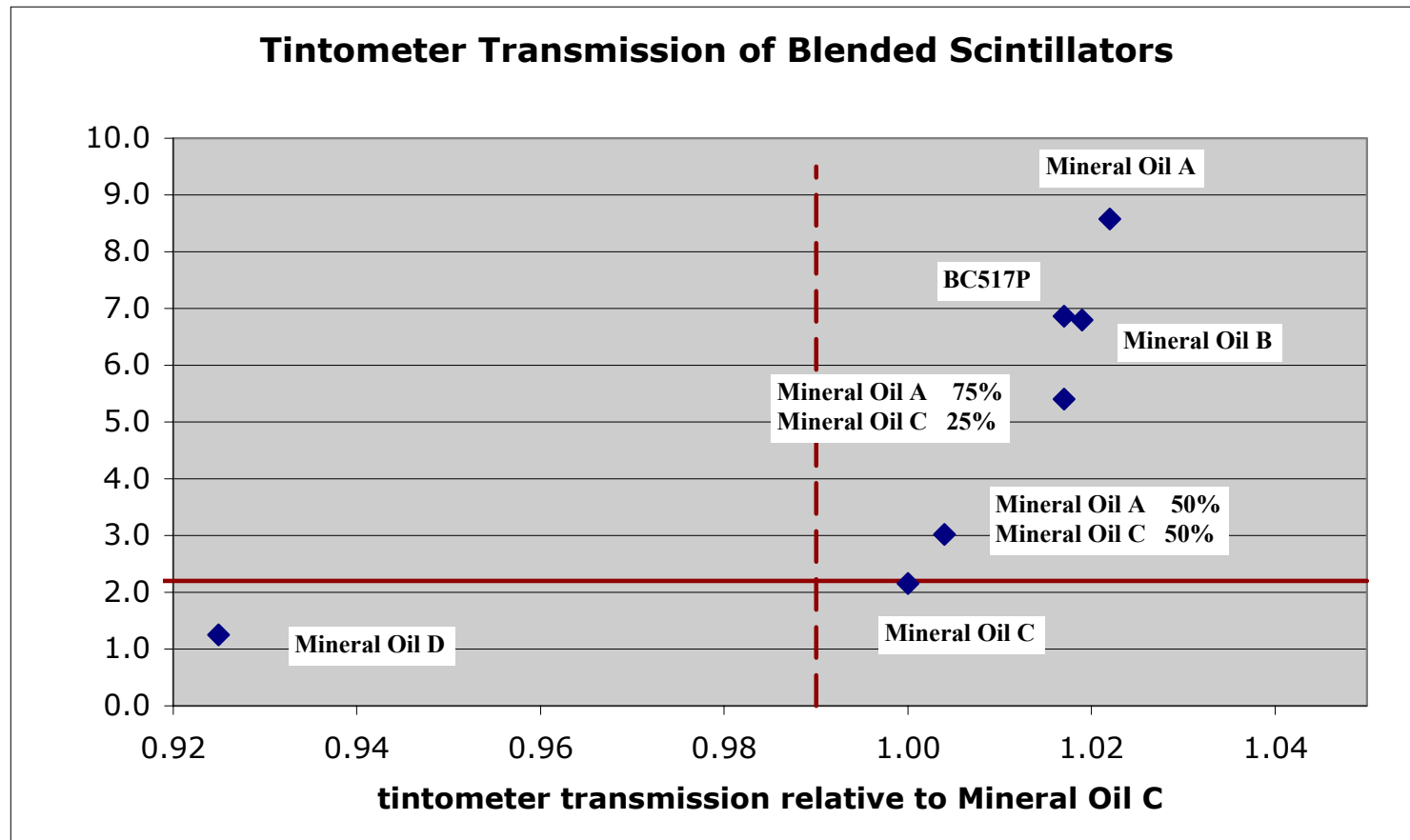


Mineral Oil C meets design requirements, Mineral Oil D does not



QA/QC --Scintillator Attenuation Length

Quick, simple testing with Lovibond Tintometer

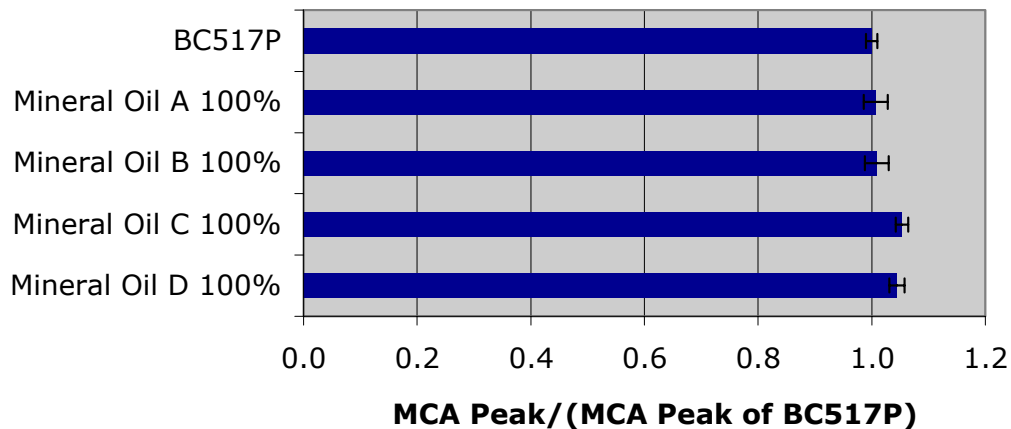


Scintillator with Mineral Oil C meets design requirements,
Scintillator with Mineral Oil D does not



QA/QC -- Scintillator Composition

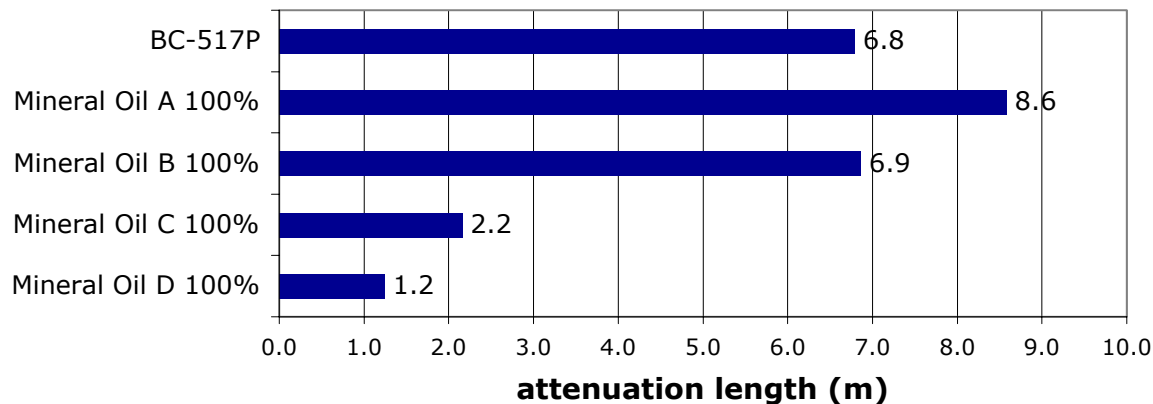
Alpha Test of Scintillators with Baseline Fluors



- The α -test is a test of scintillator composition.

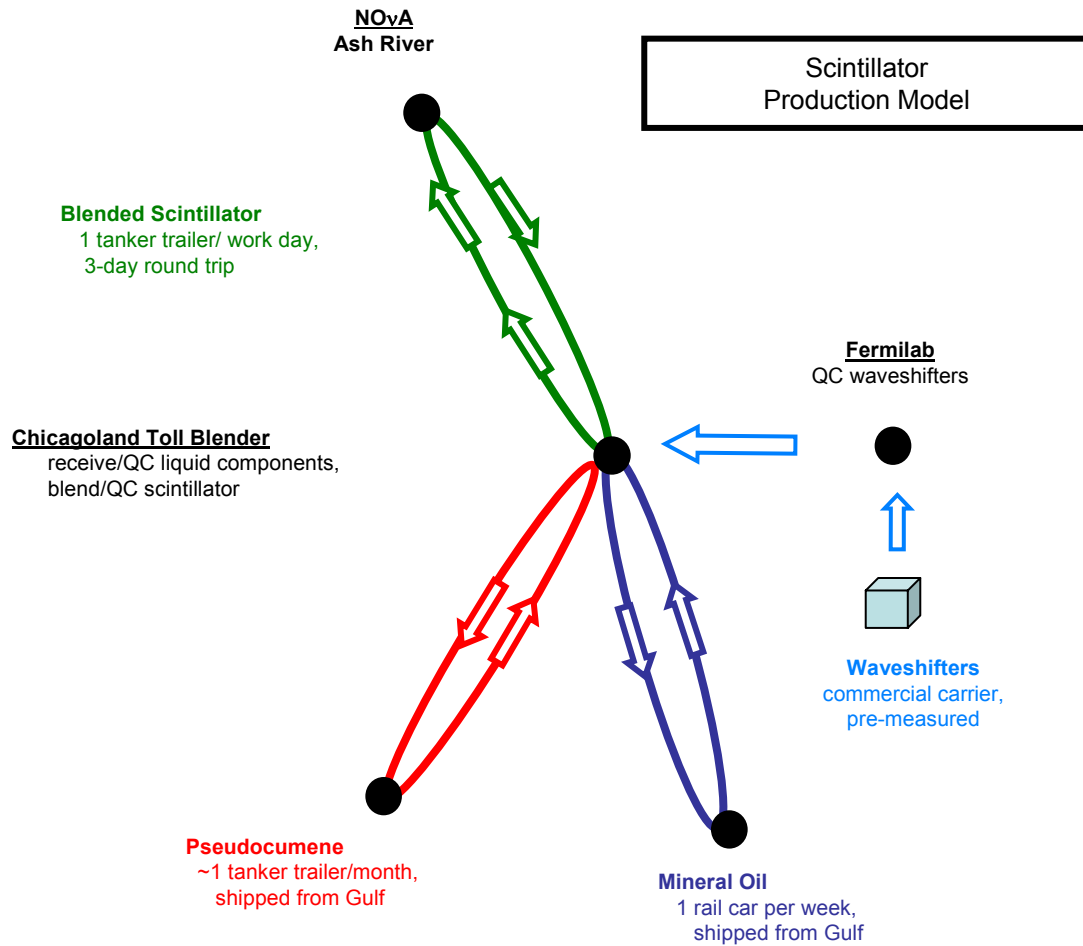
The light yield in the α -test for scintillators made with the same fluor mix is mostly independent of attenuation length of the mineral oil

Attenuation Length of Scintillators with Baseline Fluors @ 420 nm





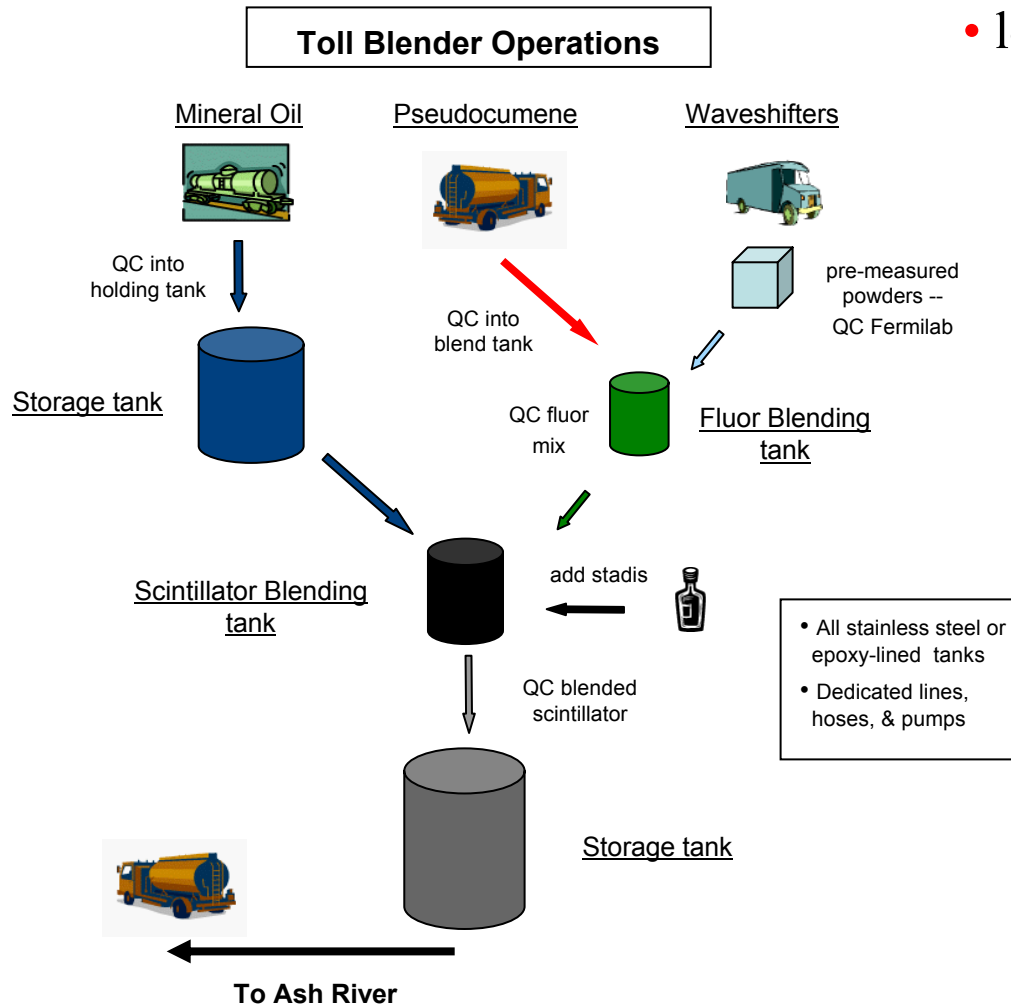
Liquid Scintillator Production Model



- NOvA liquid scintillator will be blended at a commercial toll blending facility in Chicagoland
- components purchased by Fermilab
- components delivered to toll blender by most cost-effective means in dedicated equipment
- blended scintillator delivered to Ash River by dedicated tanker trailers
- NOvA QC at toll blender



Liquid Scintillator Toll Blender Operations



- logistics:

- 3.9M gallons of liquid scintillator to be delivered in 24 months.
- 6 deliveries of liquid scintillator per M-F work week
- 3 day round trip: Chicago toll blender – Ash River – Chicago
- 12 dedicated tanker trailers required



Liquid Scintillator Logistics

- 3.9M gallons of liquid scintillator to be delivered over a period of 24 months.
 - with 7,000 gallon tanker trailers, 6 deliveries of liquid scintillator per M-F work week required
- logistics plan also driven by:
 - the 3 days time required for a driver to make the round trip Chicagoland (toll blender) – Ash River – Chicagoland
 - an empty trailer available to make an immediate return
 - no weekend driving
- 12 dedicated tanker trailers needed by this logistics plan
- logistics:
 - 3.9M gallons of liquid scintillator to be delivered in 24 months.
 - 6 deliveries of liquid scintillator per M-F work week
 - 3 day round trip: Chicagoland (toll blender) – Ash River – Chicagoland
 - 12 dedicated tanker trailers required



Design Changes since the CDR

- Liquid scintillator blending will take place at a commercial toll blending facility
 - In CDR, blending was at Fermilab
- The importance of making liquid scintillator semi-conducting has been recognized
- The tintometer has been identified as the commercial QC device that can make rapid and consistent measurements of the transmission of mineral oil, pseudocumene, and blended liquid scintillator

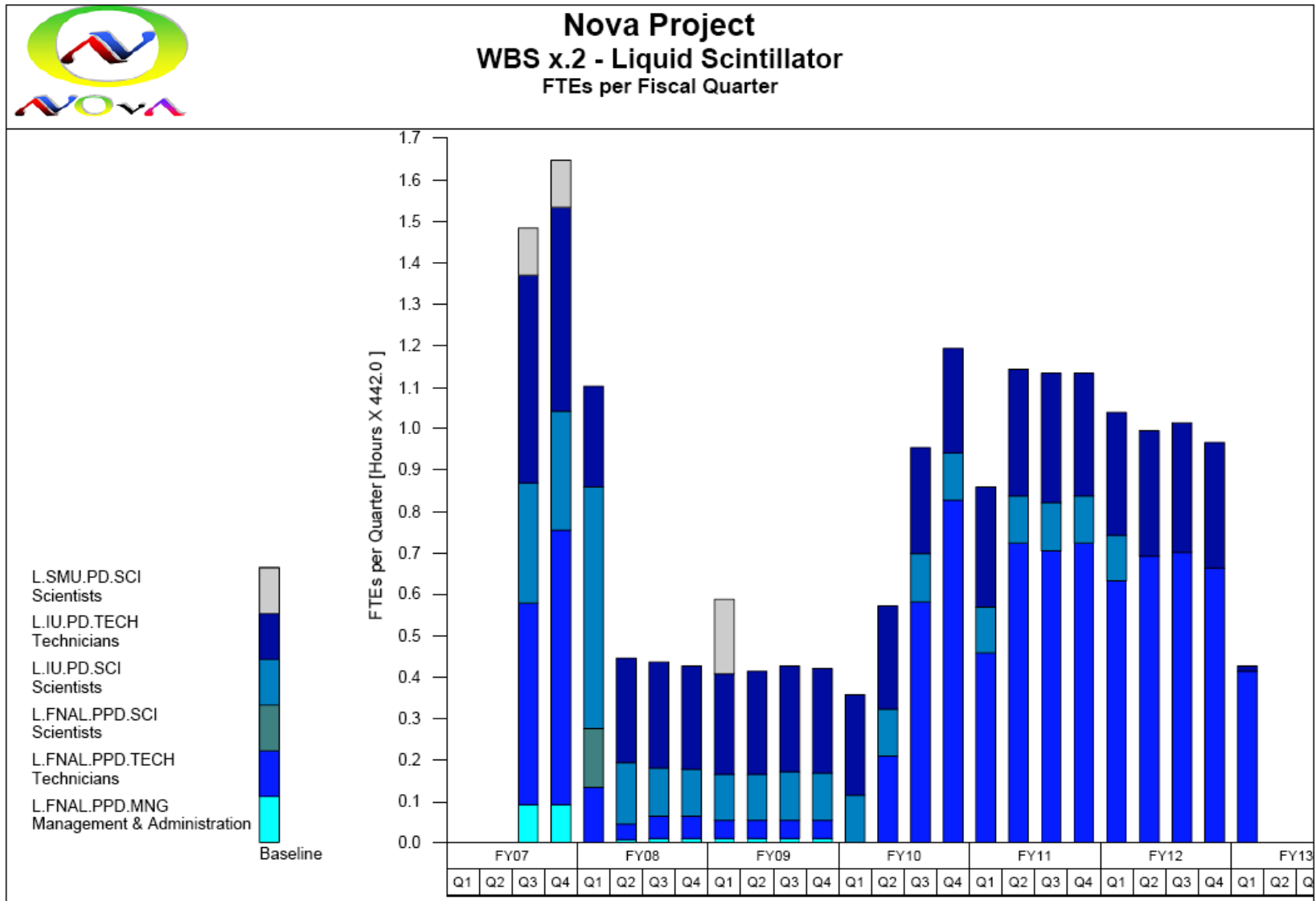


Cost & Schedule

- Requirement document -- TDR
- Milestones
 - Commodity POs issued
 - Commodities delivered
 - Production contracts signed
 - Production milestones
 - Delivery contracts signed
 - Delivery milestones
- 361 lines in Cost & Schedule



Manpower: WBS 2.2 Scintillator





Cost: WBS 2.2 Scintillator

WBS x.2 Scintillator	Estimated Cost (AY \$M)	Contingency Estimate (AY \$M)	Contingency (%)	Total Cost (AY \$M)
Construction w indirects				
M&S	23.0	6.1	27%	29.1
Labor ¹	0.4	0.3	87%	0.7
Construction total:	23.4	6.5	28%	29.8
R&D				
M&S	0.1	0.0	0%	0.1
Labor ¹	0.1	0.0	0%	0.1
R&D total:	0.2	0.0	0%	0.2

¹ Labor costs presented here include all project labor from Fermilab, other DOE facilities, and Universities.

- Cost Drivers
 - mineral oil -- \$17.2M
 - pseudocumene -- \$3.0M
 - waveshifters -- \$4.2M



Schedule: WBS 2.2




Nova Project WBS x.2- Nova_Milestones_Liquid_Scintillator Milestone Gantt Chart

Activity ID	Milestone Description	Date	FY06				FY07				FY08				FY09				FY10				FY11				FY12				FY13			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
2.2 -- Liquid Scintillator																																		
2.2.1.4	Mineral oil PO issued	27Dec07																																
2.2.2.4	Pseudocumene PO issued	27Dec07																																
2.2.3.4	Waveshifter PO issued	29Jan08																																
2.2.4.1.4	Toll blending contract signed	29Jan08																																
2.2.3.5.1	Waveshifter production and delivery begins	30Jan08																																
2.2.3.5.4	Waveshifter production 15% completed	30Sep08																																
2.2.3.5.5	Waveshifter production completed	29Sep09																																
2.2.1.5.1	Mineral oil production and delivery begins	01Mar10																																
2.2.2.5.1	Pseudocumene production and delivery begins	02Aug10																																
2.2.4.3.5	Scintillator blending begins	16Aug10																																
2.2.3.7	Stadis-425 PO issued	01Oct10																																
2.2.1.5.5	Mineral oil production and delivery 25% completed	15Oct10																																
2.2.3.9	Stadis-425 delivery completed	28Oct10																																
2.2.4.3.6	Scintillator production for superblock 1 completed	21Jan11																																
2.2.5.3.39	Scintillator delivery for first superblock completed	09Feb11																																
2.2.2.5.5	Pseudocumene production and delivery 25% completed	15Feb11																																
2.2.4.3.7	Scintillator production for superblock 2 completed	28Apr11																																
2.2.1.5.6	Mineral oil production and delivery 50% completed	10Jun11																																



Schedule: WBS 2.2 (cont.)



Nova Project

WBS x.2- Nova_Milestones_Liquid_Scintillator

Milestone Gantt Chart

Activity ID	Milestone Description	Date	FY06				FY07				FY08				FY09				FY10				FY11				FY12				FY13			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
2.2.4.3.8	Scintillator production for superblock 3 completed	02Aug11																																
2.2.2.5.6	Pseudocumene production and delivery 50% completed	25Aug11																																
2.2.4.3.9	Scintillator production for superblock 4 completed	08Nov11																																
2.2.1.5.7	Mineral oil production and delivery 75% completed	07Feb12																																
2.2.4.3.10	Scintillator production for superblock 5 completed	23Feb12																																
2.2.2.5.7	Pseudocumene production and delivery 75% completed	13Mar12																																
2.2.4.3.11	Scintillator production for superblock 6 completed	31May12																																
2.2.4.3.12	Scintillator production for superblock 7 completed	10Sep12																																
2.2.1.5.8	Mineral oil production and delivery completed	28Sep12																																
2.2.2.5.8	Pseudocumene production and delivery completed	28Sep12																																
2.2.4.3.90	Scintillator production for all superblocks completed	07Nov12																																
2.2.5.3.40	Scintillator delivery for all blocks completed	21Nov12																																



CD-3a Approval for Purchase of Waveshifters in FY08/FY09

- Waveshifters to be purchased beginning in FY08 which requires CD3a approval
 - Only vendor for waveshifters
 - Another vendor will require facilities development, most likely in China
- Rolled up cost
 - Cost are always with contingency, burdened with all overheads, escalated.
- Risk
 - The project will suffer a delay if waveshifters not purchased beginning in FY08 because of the long lead time required for a new supplier to be developed



Summary

- Technical
 - Commercial Toll blending of 3.9M gallons of liquid scintillator
- Cost
- Schedule
 - Working on it
- 3a items & their cost
 - waveshifters